

QUANTITATIVE DIFFERENCES IN PARTICIPANTS EXPOSED TO PATTERNED,
WEAK-INTENSITY ELECTROMAGNETIC FIELDS: INVESTIGATING THE SHIVA

By

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ABSTRACT

Direct and indirect stimulation of the brain have produced a range of perceptual, motor, and cognitive experiences, including experiences historically ascribed to religious or spiritual domains. Weak intensity, extremely low frequency electromagnetic fields patterned after physiological processes have been the subject of much research and controversy. The current study examined the Shiva technology, a unique method of field production that utilizes the same fields used in previous research. Quantitative changes in brain activity were measured using quantitative electroencephalograph and subjective reports of experiences were examined. The investigation included two different configurations of the Shiva technology. Results indicated that individuals exposed to specific patterned fields exhibited different patterns of neural activity and greater reports of unusual experiences compared to a sham condition. The importance of particular enhancement of power in regions of the brain due to the sequence of different patterns of magnetic fields was a key discovery. Personality characteristics, particularly those involved with the Default Mode Network, and their relation to baseline electroencephalographic data were also examined.

Keywords

Shiva Magnetic Fields; Quantitative electroencephalography; Mystical Experiences; Delta-Theta Power; Default mode network; Egocentrism; Psychometric Measurement; sLORETA; Gender differences

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Chapter 1

Introduction

1.1 Action Potential

The nervous system is composed of approximately 100 billion neurons, specialized for communicating between one unit and another. Ensembles of neurons are aggregated to allow for emergent phenomena from which a single neuronal unit could not be responsible. Communication between neurons is mediated via the action potential, a potential gradient with energy in the range of 10^{-20} J. As connected neuronal activity reaches a threshold, this energy travels down the barrel of the axon and is transferred to afferent neurons, which can cause either excitation or inhibition in these connected neurons. Although energy transfer from a single neuron can be sufficient to precipitate a cascade of neuronal activity within the brain (Li et al, 2009), generally initiating an action potential required the input of many neurons in the form of a network. It is the summed activity of many connected neurons, each contributing a small proportion of energy that can produce the level of hypopolarization required to initiate an action potential. Concomitant with the action potential, an electromagnetic field (EMF) is also produced that likewise travels down the barrel of the axon at a 90-degree angle to the direction of electric current (Kandel et al, 2000).

1.2 Columns

As any system, the behaviour of a single unit does not adequately represent the functioning of the whole system. Many individual units are required to operate together,

producing emergent properties only present when a phenomenon is viewed as a system. In the case of the brain, the unit is a single neuron. As mentioned above, most activation within the brain is a result of the summation of many neurons. Functionally and structurally similar neurons within the cortex can be group into minicolumns, a .5-1 mm² wide area that extends the depth of the cortex (Kandel et al, 2000). For example in the visual cortex, certain cortical columns respond strongest to visual stimuli that represent the orientation of a line (Hubel, 1995). Some columns produce greater activity when a line is horizontal, and will produce lower activity as the stimuli is oriented at a diagonal perspective, and less still when the line is vertical. Approximately 50-100 minicolumns are further arranged into hypercolumns, containing minicolumns that account for all response types; in the example of line orientation, a hypercolumn would contain all minicolumns accounting for the range of line orientation from vertical to horizontal. The brain consists of these nested levels of complexity, from neuron to columns to aggregates of columns specialized for certain functions. Nuclei are further specialized regions responsible for the full range of sensory, motor and cognitive processes of the brain.

1.3 Measurement/EEG

As behavioural and cognitive processes are mediated by the activity of neurons, measurement of this activity is crucial to understanding how a biological organism functions. Single-cell recordings allow for the monitoring of the activity of a single neuron (Schwalb & Hamani, 2008). It is also possible to directly influence the neuron as well. By electrically simulating a neuron an action potential is elicited causing either excitation or inhibition of its activity and influencing the neuronal network to which it is connected.

On a larger scale, the summed activity of thousands of action potentials originating from the cortex can be measured by Electroencephalography (EEG) and Magnetoencephalography (MEG) (Niedermeyer & Da Silva, 2004). Developed originally by Hans Berger (1924) the EEG is essentially a voltmeter with sensors affixed to the scalp. The voltages produced by the brain can be difficult to detect, given the greater intensity produced by muscle contraction from the rest of the body. By limiting the intensity and frequency within a particular range, artefacts from muscle movement and other sources can be minimized, leaving only those fields whose sources lie within the brain. These field potentials reliably indicate states of consciousness, clinical signs, and a variety of other cognitive phenomena (Niedermeyer, & Da Silva, 2004). While early EEG recordings could be analyzed qualitatively by the numbers of peaks within a selected time frame, advances in computing have allowed for greater quantification of data. This advancement has allowed researchers to differentiate the general wave structures into the component rhythmic frequency bands. The fields measured by the EEG represent neuronal communication. Because interpretation of this electromagnetic activity allows us to understand what is occurring within the brain, it is possible as well to influence the communication, both directly and in a non-invasive manner.

1.4 Electrical Conduction History

Recognition that electrical conduction mediates responses from the nervous system was known since at least the late 19th century, when Fritsch and Hitzig produced leg movement in dogs by applying electrical stimulation to the scalp (Schwalb & Hamani, 2008). This was subsequently replicated on a human subject by Bartholow. Cortical Stimulation Mapping, pioneered by Horsley, involved the application of an electrical

current directly to the nervous tissue to determine where the cortical activities responsible for specific behavioural, sensory, and phenomenological experiences were localized. Horsley also used electrical current as a form of treatment, by ablation of regions involved with abnormal processing via electric current. Modifications of these techniques were employed by Penfeld (Gloor et al, 1982) in his landmark studies of epilepsy and related phenomena. Deep Brain Stimulation (DBS) involves the use of electrodes implanted within the cortex, when is connected to a modulator outside of the cortex. DBS has developed as a useful form of therapy, particularly in reducing Parkinsonism and other movement disorders (Schwalb & Hamani, 2008).

1.5 Current Induction History

Although the success of applying direct current to the nervous tissue has proven effective, these procedures remain invasive. Neurosurgery can be costly and may introduce additional complications to the patient, such as infection during the surgery or through the external connection between the stimulation device and the electrode (Kenny et al, 2007). The ability to modulate cortical activity without the requirement to perform invasive surgery has been the subject of much research. Faraday discovered that time-varying magnetic fields were able to induce an electrical current in a conductor. Magnetic eddy currents produced when an electrical field is passed through a coil has been used in IBS (Induced Brain Stimulation; Geddes, 1991). The first reported discovery that magnetic fields could produce changes in neural activity was by d'Arsouval, who anecdotally found that by standing within a magnetic field of sufficient intensity, could produce phosphenes and a sense of vertigo within the individual. This was repeated by Beer, who coined the phrase Magnetophosphenes to describe the visual stimuli evoked by

field exposure. Kolin demonstrated directly that a magnetic field could produce activity in nerve tissue, by stimulating frog nerve tissue to produce movements within the leg (Geddes, 1991).

1.6 Field Effects

A variety of studies have found measureable effects on neural processing when the brain is exposed to electromagnetic fields. Arendash et al (2010) applied 918 MHz fields to populations of mice including transgenic A β PPsw mice, which overproduce the amyloid plaques observed in individuals with Alzheimer's disease. Transgenic mice made significantly more errors on a cognitive interference task, while transgenic mice exposed to the field made similar numbers of errors as normal mice who were and were not exposed to the same field. In this case, the field appears to alleviate the cognitive deficits observed in the transgenic mice. In a study looking at similar frequencies, in this case 835 MHz, Maskey et al (2010) applied a field to mice over various field intensities and durations, ranging from 1 hour/day for 5 days to daily exposure for one month. Mice were sacrificed, and expression of calbindin D28-k and calretinin, two calcium-binding proteins, were examined. One potential mechanism through which magnetic fields have been thought to exert an effect on biological systems is via calcium channels (Cifra et al, 2011), so it was reasoned that chronic exposure to fields may affect these proteins. Chronic exposure during the one-month duration produced increased dropout of these Ca²⁺ related proteins within areas CA1 of the hippocampus and dentate gyrus. Although the two results appear conflicting, they both demonstrate that exposures to magnetic fields have an effect on behavior and neuronal structure nonetheless.

Transcranial Magnetic Stimulation (TMS) is a method of producing perturbations of activity within the brain. A current was carried through a coil, producing an electromagnetic pulse, which then produced activity within the neural tissue (Chouinard & Paus, 2010). TMS is an accepted technique for altering behavior within the laboratory as well as within the clinical setting for the treatment of depression and other mood disorders (Loo & Mitchell, 2005; Thut & Pascual-Leone, 2010). These effects should not be present if the brain were not susceptible to magnetic field effects.

1.7 ELF Effects

Although the clinical applicability of TMS has been demonstrated in the literature, other research has focused on investigating the effects of extremely low frequency (ELF) and low-intensity electromagnetic fields on neurophysiology and behaviour. ELF fields are those with a frequency below 100 Hz (Marino & Becker, 1977). Whereas TMS operates within field intensities of 10^0 T range, low-intensity physiological patterned fields operate with an intensity of 10^{-6} T, several orders weaker than that of TMS (Persinger et al, 2010). The energy associated with a low-intensity field is in the range of 5 μ T (50mG). Persinger calculated that continuous presentation of the field would produce the energy of 6×10^{-9} J, which is a billion times less than the energy associated with glucose metabolism within the brain. However, with 10^{10} neurons with associated action potential energy of 2×10^{-20} J, firing with an average rate of 10Hz, the associated energy would equal that produced by the low-intensity field (Persinger et al, 2010). By producing fields that would exert their effect on the brain with the same energy associated with activity of the brain, it is theorized that these fields may be better equipped to deliver the information needed to produce the desired effects than fields of greater intensity.

Although the argument has been made that low intensity fields will lose the energy required to produce changes in neural activity (Aaen-Stockdale, 2012), it has been demonstrated that there is no significant loss of intensity when the field is transmitted across material with greater density than the skull (Persinger & Saroka, 2013).

ELF exposure has produced a wide range of behavioural effects, such as magnetophosphene perception, psychomotor effects, and changes in human EEG recordings (Marino & Becker, 1977). Bell et al (1992) exposed static and 60 Hz magnetic fields to human subjects. EEG measurements taken at the time of field exposure recorded changes over parietal and central channels, indicating that ELF exposure can be detected by the nervous system. A review by Cook et al (2002) highlighted several studies describing changes in ERP characteristics due to ELF exposure. Sartucci et al (1997) found reduced N150 and P250 wave amplitude when participants were exposed to fields within the microT range. These two waves have been implicated in pain related somatosensory perception. P300 ERP wave amplitude, involved in information processing, has also shown to be altered after exposure to ELF fields (Cook et al, 1992). Robertson et al (2010) used fields pulsed up to 300 Hz, produced by an MRI machine, while human participants were exposed to acute thermal pain. Individuals exposed to the fields had decreased activity within the right insula, anterior cingulate, and hippocampal regions, which have been implicated in neuromodulation of pain.

1.8 Persinger

Dr. M. A. Persinger has demonstrated the effectiveness of low-intensity physiological patterned magnetic fields over the past several decades. These fields are modelled after

the neuronal firing of structures within the brain. Much research examining electromagnetic field (EMF) effects has focused on various frequencies of sine waves. Patterned fields, owing to their complexity, may transmit more ‘information’ to the brain than just simple sine waves. Dynamic fields modelled after neuronal firing such as LTP (Richards et al, 1996) and firing of neurons within the amygdala (Martin et al, 2005) has been used by Persinger et al to produce a variety of quantitative changes within EEG activity and behavioural measures (2010).

A fundamental mechanism for the effects of these fields, in addition to the intensity, is the pattern. As these fields are modelled after physiological processes, presenting the information in an altered manner may not be producing the same input as when the field simulates normal processing. Tsang et al (2009) demonstrated that changing the timing of the patterned field altered its effectiveness. In that study, two fields that had been found to reduce measures of depression or mental fatigue previously were significantly more effective at replicating these effects than modified fields that utilized an identical pattern, but different intervals of timing. Two of the effective patterns used in this study were modelled after the amygdala and hippocampus, two limbic structure targeted due to their electrical lability.

The first of these, BurstX, is modeled after the burst-firing pattern of neurons in the amygdala (Figure 1). This pattern has shown to be effective in producing an analgesic effect in rats (Martin et al, 2005), to evoke pleasant feelings in human participants (Freeman & Persinger, 1996), and to elicit the ‘sensed presence’ experience (Cook & Persinger, 1997).

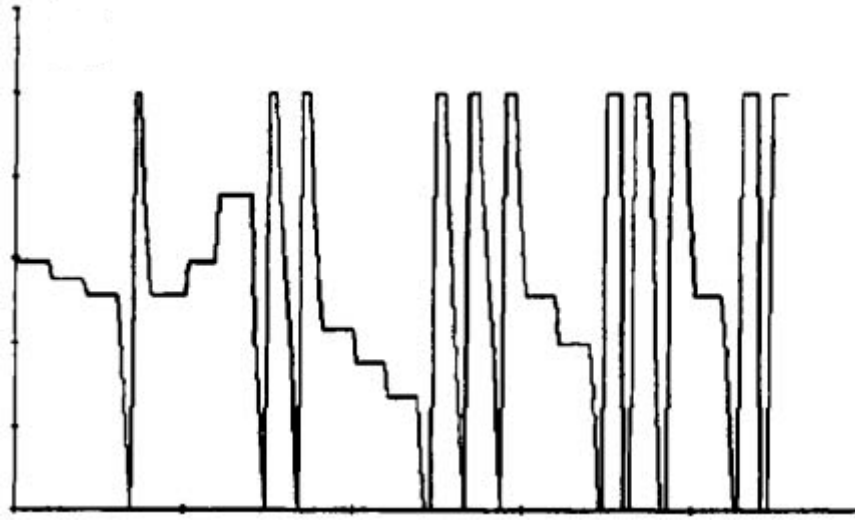


Figure 1 – Image of Burst-X field pattern (St-Pierre et al, 2008).

The second field is the LTP (Long-Term Potentiation) field. It is based on the algorithm for induction of LTP (Rose et al, 1988) within the hippocampus (Figure 2). Richards et al (1996) found that stimulation of the left hemisphere with the LTP field produced greater accuracy while the participant attempted to reconstruct a 5-minute narrative. Prenatal exposure to the LTP field in rats has produced neuronal loss in the CA1 and CA2 fields of the hippocampus, but not the amygdala (Whissell et al, 2009), lending support to the notion that this particular pattern may be targeting a specific limbic structure.

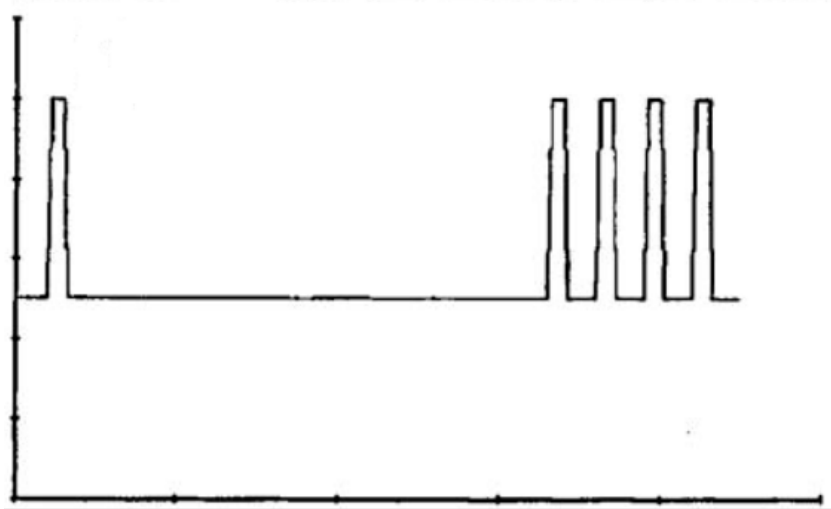


Figure 2 – Image of Long Term Potentiation (LTP) field pattern (St-Pierre et al, 2008)

Although dynamic fields represent an improvement upon static field exposure, other research has shown that the presentation of several fields in a particular sequential order additionally may produce a greater effect. By applying fields first over the right hemisphere followed by bilateral exposure, St.-Pierre & Persinger (2006) reported greater success at eliciting EEG and subjective experience report changes, demonstrating that it may be important to use not only patterned fields, but using a specific sequence of different, patterned fields to elicit desired effects.

1.9 Shiva

Field delivery has been conducted using devices such as the Koren Helmet (Cook & Persinger, 1997) or the Octopus (Tsang et al, 2009). If the patterns of the fields are the critical factor behind the reported effects, and not the equipment itself, than results should generalize to other pieces of hardware provided that the characteristics of the patterns remains constant. Working in collaboration with Dr. Persinger of Laurentian University, Todd Murphy has created the SHAKTI and Shiva helmets. The equipment uses patterned fields identical or very similar to those employed in previous studies, but utilizes a novel method of field application. Patterned waveforms are converted into audio files, which are delivered from USB soundcards to solenoids on the helmet (Saroka et al, 2010; Figure 3).

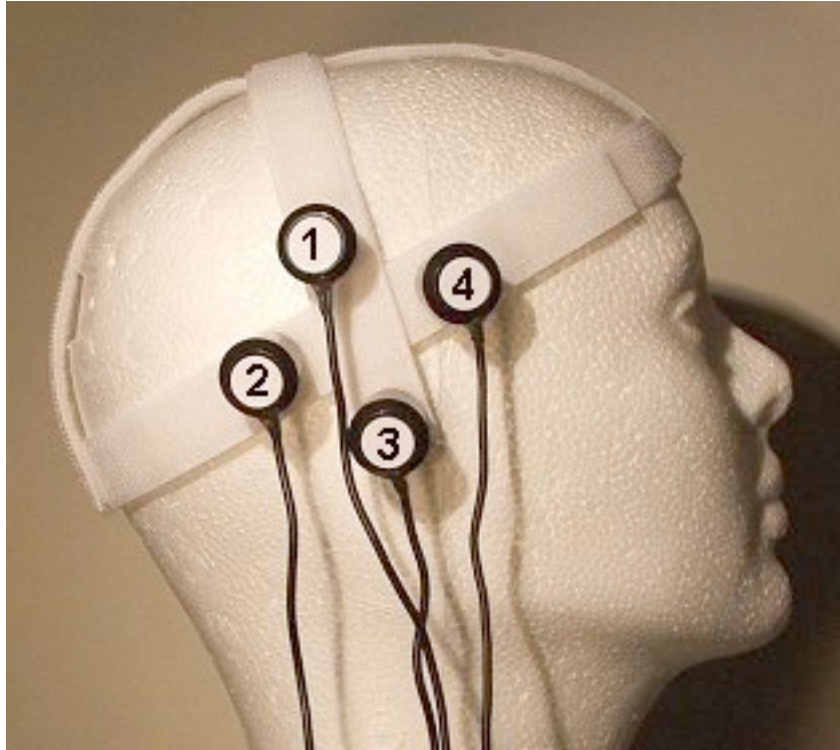


Figure 3 – Right hemisphere view of the Shiva technology

The resultant activation of the solenoid creates a weak-intensity magnetic field within the μT range. This alternate technique of producing patterned fields has been effective in producing changes in quantitative physiological measures. In a study by Tsang et al (2004), an earlier version of the Shiva hardware named 'Shakti' was used to expose participants to similar fields used by Persinger for four consecutive weeks. EEG measures found that after the four weeks of treatment, individuals exposed to the Shakti treatment had elevated levels of high alpha (10.5 Hz to 13 Hz) activity over frontal, temporal, and parietal lobes, as compared with individuals exposed to a sham field. In a study by Saroka et al (2010), a case study involving a participant exposed to a Burst-X modeled field was presented. An anomalous subjective report of an out-of-body experience while being exposed to the Shiva helmet in a 64-coil configuration was accompanied by increased coherence between (left temporal and right frontal) lobes. This pattern of coherence has been observed previously in out-of-body experiences that have been elicited by exposure to fields using the Koren helmet and related technologies (Persinger et al, 2010).

1.10 Criticism

Criticisms for the effectiveness of these particular patterned fields have been reported by Granqvist et al (2005). The Shiva method of producing fields itself has been the subject of criticism. In a study by Gendle & McGrath (2012), the Shiva was found to be ineffective in altering subjective emotional experience. Participants were exposed for 30 minutes to either fields created by the Shakti or to a sham condition. Participants then

rated a 54-image modified version of the International Affective Picture System (Del Seppia et al, 2006) to see if there were differences in ratings of emotional reactions to the images. There was no significant difference for the ratings between groups, implying that the fields did not create altered emotional responses.

However, there may have been several methodological issues with the study itself that perhaps make these findings inconclusive. Testing was conducted in a normal room, as opposed to a chamber shielded from environmental fields. As these fields are low-intensity, they may be prone to external fields such as those produced by nearby electronics or from variations in the earth's magnetic field. Like the aforementioned Granqvist study, no physiological measures of neural activity was taken, leaving no way to determine if the field produced a physiological effect that may not have been represented in the task itself.

Most critical of all is the task itself. The emotional images used in this study were based upon those used in a previous study by Del Seppia et al (2006). In that particular study, magnetic fields were applied to human participants in an attempt to change the subjective emotional responses to a set of images. The task consisted of viewing images and rating it on a dichotomous visual analogue scale between two emotion words, e.g. 'anxious' vs. 'calm'. There was no significant differences found between individuals in the field and sham conditions. If the fields in that particular study had any effect on subjective experiences, this particular measure may lack the sensitivity required to identify differences. In light of this, using a test that has found null results in one study and applying them to a similar Gendle and McGrath study, it is not surprising that no significant effect was discovered.

According to the other studies however, the corroborating results thus far found with Murphy's equipment indicate that the effects appear due to the pattern of the fields, and not the equipment. However, the experimental evidence thus far has been limited, with the majority of claims coming from testimonials. One criticism of the Persinger studies is that the effect is specific to the equipment itself. The intent of the current study is to test the range of fields produced by the Shiva helmet in an experimental setting and to determine if effects found in the Persinger equipment can be replicated in other hardware not made by Persinger and using an alternate method of producing the fields

1.11 Study 1 – Shiva Helmet

In the first study, the Shiva Helmet was investigated to determine if there were any physiological or subjective experiences elicited by a field produced by the Shiva equipment. The field used in this study is the Amygdaloid/Burst-X field. This is the field that has previously shown effects at alleviating mood (Freeman & Persinger, 1996), and is the field used with the Shakti in the Gendle & McGrath Study (2012). This study used a Shiva helmet with 64-coils that were activated in a counterclockwise, circumcerebral manner. Five participants were exposed to the field for 20 minutes, while 4 wore the helmet but were not exposed to a field condition. Physiological changes as measured by EEG activity were recorded, and a questionnaire exam was given to all participants upon completion of the study.

1.12 Study 2 – PPI/DMN

The second study was designed to examine the relationship between personality traits and the underlying baseline, eyes-closed EEG sample. The contribution of suggestibility to

the effects produced by these fields has been discussed by both Persinger and his critics. Granqvist et al (2005) contend that effects observed by Persinger are the result of suggestibility of the participants, and not the equipment itself. Persinger contends that while there is a role for suggestibility, it is an interaction with the field effects, i.e. underlying brain functioning of individuals who are suggestible makes them more susceptible to field effects. This study used a database of 56 participants who completed both the Personality Philosophy Inventory (PPI) and an eyes-closed resting EEG baseline recording. Relationships between personality traits and baseline EEG activity were examined, with particular emphasis placed upon the role of egocentrism and the default mode network. Gender effects were also examined.

1.13 Study 3 – Shiva God Helmet

In the third part of this study, the Shiva God Helmet was examined. This equipment uses the same equipment as in the first experiment, but it is in a different configuration. Eight coils are used, with four being placed over each of the participant's temporal lobes, for a total of 8 solenoids. Software provided by Murphy contains eight field conditions. Each condition consists of two separate fields lasting 20 minutes each, for a total of 40 minutes. 24 participants were included in the study, with three in each of the eight conditions. Participants were given the PPI before exposure and were given an experiences questionnaire upon completion of the field condition. EEG recordings throughout the experiment were compared across conditions, and personality factors predicting experiences were examined.

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Chapter 2

Changing Velocity Circumcerebral Magnetic Fields Produce Altered State Experiences and Lowered Delta-Theta Power over the Temporal Lobes

Abstract- Weak physiologically patterned magnetic fields applied through the cerebrum have been associated with opiate-like effects and mystical experiences including sensed presences and out-of-body experiences. While sitting in a comfortable chair housed in an acoustic chamber volunteers were exposed to Murphy's Shiva Hat from which cerebrally rotating, angularly decelerating magnetic fields (about 1 microTesla) were generated from arrays of 64 solenoids for 20 min. The sham-field exposed group wore the same hat and sat in the same place for the same duration of time. Individuals exposed to the burst-firing pattern generated fields with the changing angular velocity reported more out of body and sensed presence experiences than did the sham field group. Unlike the sham field group who displayed relative increases in delta power over both temporal lobes during the sessions, those exposed to the field exhibited diminished power that was comparable to their original aroused state. These results suggest that the effects of weak, complex magnetic fields on cortical electroencephalographic activity are consistent with patterns of cortical activation during altered states.

Keywords- Shiva Magnetic Fields; QEEG; Mystical Experiences; Delta-Theta Power

2.1 Introduction

One of the basic premises of modern psychology is that all experiences are generated by brain activity. Experiences that are ephemeral and profound, such as mystical experiences that include the sensed presence and out-of-body experiences (often reported during altered states) should be elicited within controlled experimental conditions. We have been pursuing the assumption that conscious experience involves relatively low energies, in the order of 10^{-12} Joules (J) which would be equivalent to about 10 million neurons each discharging with 10 action potentials per second and each action potential generating about 10^{-20} J (Persinger et al, 2010; Booth et al, 2005). In fact according to the classical formula $\text{energy} = (B^2 / (2 \cdot 4\pi\mu)) \cdot m^3$, where B is the strength of the field, μ is permeability, and m^3 is volume, a 1 milligauss (0.1 microTesla) magnetic field within the volume occupied by the cerebrum (about 10^{-3} m³) would be associated with between 10^{-11} and 10^{-12} J of energy. Such intensities are frequently encountered within the modern electronic world (Saroka and Persinger, 2011).

Although there is replicable evidence that physiologically-patterned magnetic fields applied across the cerebral hemispheres produce experiences of sensed presences in double-blind experiments (Persinger, 2003) when the software is properly applied, subjective experiences are extremely sensitive to context and the ability for the experient to label the experiences. Quantitative electroencephalographic analyses (Persinger et al, 2010) employing coherence analyses found that during sensed presences the vector of right temporal lobe processes pointed towards the left temporal lobe. On the other hand

during out of body experiences the vector was from the left temporal lobe to the right prefrontal region. These results were consistent with the hypothesis that the sensed presence is the left hemispheric awareness of the right hemispheric equivalent of the left hemispheric sense of self. On the other hand the out of body experience is the intrusion of left hemispheric (awareness) processes into right hemispheric cognitive operations involved with spatial location and reconstructed memories.

The Shiva series was developed by Todd Murphy employing a wave-file type technology to apply the patterns of magnetic fields. They differ from the format employed by Persinger et al (Booth and Persinger, 2009) where point durations of 3 ms of voltages between -5 and +5 V were generated from custom-constructed digital-to-analogue converters that produced current within connected arrays of solenoids or coils to generate the magnetic fields. The Shiva system is a commercial device that claims to facilitate personal development. There are myriad on-line testimonials concerning the efficacy of the equipment. We decided to examine the Shiva experience within the appropriate laboratory condition and to discern if: 1) subjects endorsed mystical-like experiences during these altered states, and, 2) if there were discernable changes in the electroencephalographic power particularly over the temporal lobes which have been considered the primary source of these phenomena. We reasoned if the effects were as large as reported they should be evident with even a small sample size.

2.2 Method

2.21 Subjects

After approval by the university's Research Ethics Board, 9 university men and women

volunteered to participate in the experiment. Their ages ranged from 20 to 25 years. Five (3 men, 2 women) of the subjects were exposed to the magnetic field condition while the other 4 subjects (2 men, 2 women) were exposed to the sham field condition. In the latter situation all procedures were identical except that no magnetic fields were activated.

2.22 Procedure

Each subject was told he or she might or might not receive weak intensity magnetic fields. The subject sat in a comfortable chair in a quiet, dark room that was also a shielded acoustic chamber. An ELECTRO-Cap international electrode system with 19 AgCl electrodes was placed over the head and referenced to the ears for collecting monopolar EEG data. Impedance under 15 kOhms was verified and maintained for each sensor. The EEG cap was connected to a portable laptop outside the chamber employing a Mitsar 201 amplifier system. WinEEG version 2.84.44 working in Microsoft Windows XP was used to collect the EEG data.

A custom-constructed (construction worker) hat supplied by Professor Todd Murphy was placed over the EEG cap. Over the surface of the hat there were 8 columns of 8 (64) solenoids obtained from Radio Shack. The 8 rows of solenoids were separated at equal angles around the hat so that the entire cerebrum received focal, weak magnetic fields for pre-programmed periods (Figure 4). Signals were transmitted to the successive rows of solenoids on the surface of the hat using Shiva Neural Stimulation Software version 5E. This software was also designed by Professor Murphy and employs 4 USB audio devices to send weak-intensity magnetic fields to the solenoids. The signals were derived from patterns described by Richards et al (Richards et al, 1993). For this technology the

digital-to-analogue signals had been transformed to audio-equivalents or wave files. Each USB audio device delivered the signal to two successive solenoid columns.



Figure 3 - The Shiva Device being worn by a volunteer while sitting within the experimental chamber. The device is controlled by computer programs and materials external to the chamber

The pattern selected for the present study was designated as “amygdaloid signal, normal speed”. This pattern was derived from “burst-firing” neurons within the amygdala and when applied as whole body fields to rodents results in analgesia equivalent to about 5 mg/kg of morphine (Martin et al, 2004). The signal is composed of 289 points each generating a voltage between -5 and $+5$ V to each pair of rows of solenoids. The duration of the pattern for the left frontal row of solenoids was 100 ms. Each successive column (counterclockwise from the top) was activated for an additional 20 ms. The point duration of each of the 289 points was 3 ms with 4000 ms (4 s) between each cycle. The duration of the total exposure was 20 min. The strength of the time-varying magnetic field within the volume occupied by the subjects’ heads was about 10 mG (1 microTesla).

The subject was instructed to maintain closed eyes during the duration of the experiment. At the end of the experiment each subject completed an exit questionnaire listing 20 items (Persinger, 1999) of common experiences within the chamber. Each item was ranked according to the incidence of these experiences (0=no experience, 1=happened once, 2=occurred frequently). These experiences referred to visual, auditory, tactile, vestibular and spatial anomalies as well as the sensed presence, out-of-body experiences, and a variety of emotions including fear and sadness.

2.23 Statistical Analysis

Raw spectral power was extracted from the EEG data within the WinEEG software. Two, 30 s samples were captured for each individual during baseline (before the fields were activated) and 5, 10, 15, and 20 minutes after the commencement of the treatment or sham field procedure. The spectral analyses partitioned the EEG data into delta (0-3 Hz),

theta (4-7 Hz), alpha 1 (8 to 10.5 Hz), alpha 2 (10.6 to 13 Hz), beta (14-30 Hz) and gamma (30+ Hz) bands. All statistical analyses involved SPSS 19.0 operating by Windows 7. Mean scores for subjective experiences were assessed by a t-test. The responses to each item were discern by Pearson r correlations (0=sham; 1=field), such that positive correlations indicated more endorsements for subjects in the field applied group. The r^2 value offers an approximation of the effect size. To accommodate individual differences in cerebral EEG power the raw values for each temporal increment for each band were divided by the baseline value. With and between subject ANOVAs were completed.

2.3 Results

2.31 Subjective Experiences

The proportion of positive responses to all experiences was significantly [$t(7)=3.11$, $p=.01$] greater for the field exposed group ($M=35\%$, $SD=14\%$) compared to the sham field (control) group ($M=9\%$, $SD=9\%$). The group exposed to the magnetic pattern displayed significantly [$t(7)=2.73$, $p < .05$] more ($M=1.4$, $SD=0.9$) feeling of being detached or “leaving” the body than did the sham group ($M=0.0$, $SD=0$) and more intense experiences [$t(7)=3.09$, $p < .01$] of being somewhere else ($M=1.6$, $SD=.55$ vs $M=0.5$, $SD=0.5$). Pearson r values for the correlations between conditions (0=sham, 1=field) and the range of occurrence of the experiences (0, 1, 2) reflected the effect sizes. They were: I felt dizzy or odd (0.60), I felt the presence of someone or something (0.58), I felt as if I had left my body or was detached from my body (0.74), I experienced terror or fear (0.60) and I felt as if I were somewhere else (0.76).

2.32 QEEG Profiles

The major QEEG responses involved the attenuation of power within the delta and theta bands for the group exposed to this specific magnetic field configuration. The effect was time-dependent as shown in Figure 5. Whereas the group exposed to the sham field displayed increased relative delta power over the left and right temporal lobes only over the 20 min period those exposed to the Shiva amygdaloid field displayed power densities that did not change from baseline. A similar effect was noted for theta activity (not shown here) but was not evident for any of the higher frequencies except for alpha over the occipital lobes only.

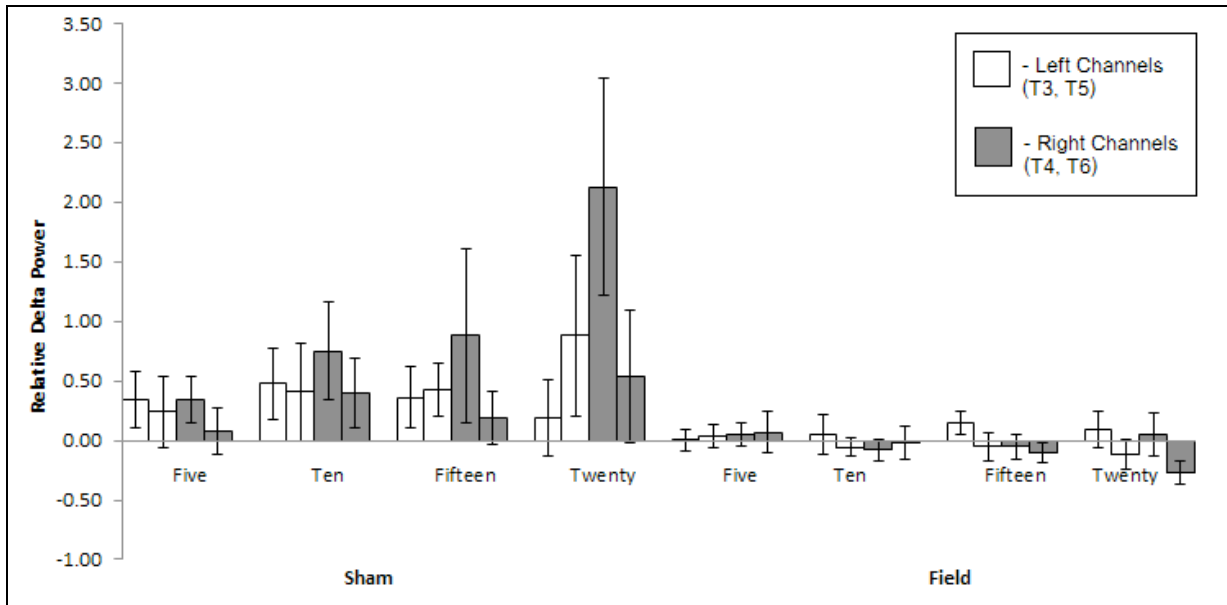


Figure 4 - Relative (to baseline) power within the delta band over time (5, 10, 15 and 20 min) for the subjects exposed to the sham field condition or to the amygdaloid burst pattern. Both groups of subjects wore the Shiva hat but a field was generated only for the field subjects. Vertical bars indicated standard errors of the mean.

2.4 Conclusions

There have been multiple reports that altered states and mystical experiences can be induced within controlled experimental conditions through strategic application of physiologically patterned weak magnetic fields whose temporal-spatial parameters are designed to interact with consciousness (Persinger, 2003). Rotational parameters that involve changing angular velocities around the head in a counterclockwise direction such that the fields are “colliding with the rostral-caudal transcerebral magnetic fields generated naturally are particularly effective for altering subjective experiences (Cook et al, 1999). However the most valid measure of discerning if a “state” has been altered requires quantitative electroencephalographic measures.

In the present study the group exposed to this specific field did not display the usual increased power within the delta range as they sat within the quiet, darkened chamber. Instead they remained relatively activated compared to baseline conditions.

Whether or not this stability was associated with the subtle energy generated by the fields within the cerebral volume remains to be verified. That the effect was specific to the temporal lobes and not to the entire cerebrum indicates that the conspicuous consistency of power measures over time was not due to artifacts or confounding induction currents. Considering the circumcercerbal rotation of the applied fields, the latter should have been diffuse.

The experiences of detachment and out of body experiences reported in this study were similar to the effects reported by Saroka et al (Saroka et al, 2010) with the same Shiva device but slightly different software and parameters. In that study there was also a

marked relative increase in delta power (2 Hz in particular) over the left temporal lobe while the person was experiencing an out-of-body experience. We did not measure left temporal-to-right frontal coherence in this study. In the Saroka et al (2010) study this coherence during the out-of-body experiences was twice that of periods when the eyes were simply closed.

There are obvious advantages of measuring QEEG activity at the same time of the field applications or sham conditions. Although St-Pierre and Persinger (2006) indicated that the incidences of a sensed presence during application of different but physiologically patterned magnetic fields were not related to the subjects' directly measured hypnotic induction profile, changes in specific power of EEG activity during field applications are more direct verifications of physical effects. As functional Magnetic Resonance Imaging data have shown, discrete enhancements of activity can occur in specific loci without the subject's awareness. Changes in power as a primary measure also minimize the dependence upon subjective report which can often be influenced by "analytical overlay", that is the person's interpretation and verbal labeling of experiential content evoked by the applied magnetic field configuration.

The results of these experiments do not prove that all experiences reported during exposure to the Shiva system or related devices are elicited by the physiologically patterned magnetic fields. However two separate experiments have shown that the out-of-body experience is predominately reported in this context compared to sham field exposures. Because all experiences are generated by or certainly very strongly correlated with brain activity, we would expect that synthesized patterns that are congruent with the neuronal electromagnetic substrate by which these natural experiences occur should

reproduce very similar experiences.

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Chapter 3

Enhanced Power Within the Default Mode Network In Normal Subjects With Elevated Scores on an Egocentric Scale

Abstract

Integrated global power from the primary structures that composed the Default Mode Network (DMN) and from a random collection of other structures were measured by sLORETA (standardized low-resolution electromagnetic tomography) for young university volunteers who had completed an inventory that contained a subscale by which egocentricity has been inferred. Subjects who exhibited higher scores for egocentricity displayed significantly more power within the DMN structures relative to comparison areas. This was not observed for individuals whose egocentricity scores were lowest where the power differences between the DMN and comparison structures were not significant statistically. DMN power was greater in the right hemisphere than the left for men but greater in the left hemisphere than the right for women. The results are consistent with our operating metaphor that elevation of power or activity within the DMN is associated with greater “love”, “bonding” or affiliation with the self and its cognitive contents.

Keywords:

Default mode network, Egocentricism , Quantitative electroencephalography

Psychometric Measurement , sLORETA , Gender differences

3.1 Introduction

The default mode network (DMN) for intrinsic brain activity involves a neuroanatomically-based cluster of networks that are more likely to be activated when the conscious person is not focused upon the external environment. In other words there is a network of pathways involved primarily with the medial prefrontal, anterior cingulate, posterior cingulate and inferior parietal regions which demonstrate increased power or energy utilization when the person is sitting awake with minimal exteroceptive stimuli. The assumption is that the cerebral activity, in a manner similar to eliminating the input to an electroencephalographic system but increasing the gain, reveals the intrinsic activity of cerebral circuitry.

If structure dictates function then the greater involvement of these regions should determine the quality and themes of experiences that dominate the default mode. A blend of the somatosensory organization of the boundaries of the body, language-correlated imagery, and the free-associative but organized “stream of consciousness” mediated by the prefrontal regions should predominate. Because of the involvement of the anterior cingulate and the medial prefrontal regions, one would expect increased affect and “bonding” to this process. Stated alternatively, the normal person should be “in love” with his or her own thought processes and may find them as enjoyable as any low-level opioid-like process that is frequently associated with activation in this area (Kringelbach et al, 2010).

Research has indicated that an overlap between the areas activated during retrieval of autobiographical memory and the DMN exists. Ino et al (2011) found that the

components of the DMN that were functionally related to autobiographical memory were observed in left-lateralized brain regions. This apparent contradiction with many studies that indicate that the active retrieval of autobiographical memory involves preferential activity of the right prefrontal region while left prefrontal activity emphasizes encoding (Buckner & Petersen, 1996) can be accommodated if one assumes that during engagement of the default mode retrieved autobiographical memories are re-encoded.

Changes within the DMN has been reported for depressed patients who experience a marked increase in self-inspection and rumination whose themes are strongly dominated by the negative and dark content from largely mesiotemporal structures that have been disinhibited by hypometabolic prefrontal regions. In depressed patients the activity of the DMN does not decrease during tasks, as it does for normal individuals (Sheline et al, 2008). Although the comparison between “obsession” or repetition of negative thoughts concerning the self, including self-destructive impulses, and “addiction” to the content of the ideation may be considered overinclusive, the similarities are striking. A similar pattern has been observed for certain types of dementia (Irish et al, 2012).

We reasoned that if the DMN was that powerful it should be associated with increased psychometric indicators by which egocentrism has been inferred. Sheng et al (2010) found greater task-related deactivation in the medial prefrontal cortices for individuals who scored higher (equivalent to $r=0.46$) on the Machiavellian Egocentricity scale that assesses narcissistic and ruthless attitudes during interpersonal functioning. In the present study we predicted that average university students who scored higher on an egocentric scale derived from the Personal Philosophy Inventory or PPI (Persinger &

Makarec, 1983; 1986; 1991; 1992) should display more activation within the DMN as inferred by increased power measured by sLORETA or low resolution electromagnetic tomography during the default state, that is, relaxing and “day dreaming”, within a quiet (echoic), darkened chamber.

3.2 Materials and Methods

3.21 Participants

Sixty (60) volunteers were recruited from the general university community for participation in the study. In the final analyses due to incomplete records there were 56 participants (20 men, 36 women).

3.22 The Psychometric Tool

The items that comprised the egocentric scale from the Personal Philosophy Inventory or PPI are shown in Table 2. The main-ego scale was composed of 6 items while the primary egocentric scale for the original cluster from the PPI was composed of 12 items. The six items were extracted following the original factor analyses. The PPI was initially developed as a psychometric indicator of sensitivity or “lability” within the temporal lobes. Construct validity and cross-validity for the clusters by which electrical lability within the temporal lobes has been inferred have been established (Makarec and Persinger, 1990).

For 1,211 cases from our major data base (Persinger and Makarec, 1992), the average of the individual item correlations with the mean of the 6 items, derived from factor analyses of 12 items that displayed “face validity” as related to “egocentrism”, that

composed the egomain scale ranged from $r=0.44$ to 0.55 . The Cronbach's alpha correlation for reliability within items was 0.43 . The means and standard deviations in the sample were $52(25)\%$ for the 509 men and $40(24)\%$ for the 702 women in the sample. The gender difference was statistically significant [$F(1,1209)=88.99$, $p < .001$; $\eta^2 = 7\%$]. The individual correlations for each of the other 6 other items in Table 1 were correlated between 0.08 and 0.58 ($M=0.43$) with the mean value for that cluster. The alpha correlation was 0.08 .

A subset of the total population (120 men, 153) women who had been given the PPI and the Minnesota Multiphasic Personality Inventory over four successive years indicated that men's affirmative responses were ($M(SD)=49(24)\%$ while women's scores were $41(28)\%$. This increased score for the egomain cluster for men compared to the women was statistically significantly [$F(1,271)=5.13$, $p < .05$]. All of the means of the MMPI scaled (T) scores ranged between 46 and 60 for the three validity and 10 clinical scales. The egomain score was significantly correlated (all $p < .001$) only with the following subscales of the MMPI: Depression (-0.27), Hypomania (0.32) and Social Introversion (-0.26).

3.23 Measurements and Data Analyses

EEG recordings were completed for each person as he or she sat for 30 min in a comfortable chair within a dark, quiet chamber that was also acted as a Faraday cage. An ELECTO-cap international electrode system with 19 AgCl electrodes was placed over the head and referenced to the ears for collecting monopolar EEG data. Impedence under $10\text{ k}\Omega$ was verified for each sensor. The EEG cap was connected to a portable laptop outside

the chamber and employed a Mitsar 201 amplifier system. WinEEG version 2.84.44 working in Microsoft Windows XP was used to collect the data.

Source localization analysis was computed on the EEG data using Standardized Low Resolution Electromagnetic Tomography (sLORETA; Pascual-Marqui, Esslen, Kochi, & Lehmann, 2002). sLORETA uses standardized current density to calculate intracerebral generators of cortical activity and has low resolution but ideally zero localization error in the presence of measurement and biological noise (Pascual-Marqui et al., 2002).

Regions of Interest (ROI) were computed by selecting Talairach coordinates and a surrounding 5 mm radius. Three regions identified in literature as belonging to the DMN were selected: the Medial Prefrontal cortex (Broadman Area 10), the Posterior Cingulate cortex (BA23), and the Inferior Parietal cortex (BA34). Three ROIs not associated with the DMN were likewise extracted: the Primary Visual cortex (BA 17), Frontal Eye Fields (BA 8), and the Primary Auditory cortex (BA 41). Separate ROIs for both left and right hemispheres were extracted for each structure. Total spectral power was separated into the traditional EEG Bands of Delta (1-4 Hz), Theta (4-7.5 Hz), Alpha1 (7.5-10 Hz), Alpha2 (10-13 Hz), Beta1 (13-20 Hz), Beta2 (20-30 Hz) and Gamma (30+ Hz).

All data was imported into SPSS 19.0 for Windows 7. Fifteen-second eyes-closed baseline EEG raw power segments were extracted from each individual. An overall DMN score was computed by first summing all band powers for each ROI, and then averaging the total power of the three DMN ROIs for each hemisphere, which was likewise computed for the non-DMN structures.

3.3 Results

The results of this study supported our hypothesis that higher scores for six key items (egomain) from a psychometric inventory by which egocentrism is inferred would be associated with more power within the structures that comprise the DMN. To limit the diluting effect of dichotomizing the scores below and above the mean, participants' scores were divided into low ($n=24$; $M=42\%$) medium ($n=18$; $M=32\%$; $SD=7\%$) or high ($n=14$; 25% , $SD=10\%$). This analysis was conducted on only low and high groups to minimize impact of medial scores.

Three-way analysis of variance involving between the two groups with the upper and the lower egocentric scores and the two within levels (DMN vs reference; left vs right hemisphere) was completed. There was a significant interaction between the egocentric grouping and DMN vs reference structure activity [$F(1,36)=6.76$, $p < .01$; $\eta^2=.16$]. The source of the interaction was due (see Figure 6) the greater activation levels of the group who scored highest on the egocentric scale compared to those who score lower. Except for the obvious differences in power between DMN and references structures [$F(1,36)=46.22$, $p < .001$] there were no other statistically significant effects. Scores for individual structures did not differ from left to right hemispheres, with the exception of the Posterior Cingulate Cortex (a component of the DMN) with a main structure cluster effect ($F_{(1,31)}=4.81$, $p=.036$, $\text{partial } \eta^2=.13$) and the Primary Auditory Cortex (a component of the reference structure) with an interaction between structure and Egocentrism ($F_{(1,31)}=4.70$, $p=.038$, $\text{partial } \eta^2=.13$). Total power means for each structure and DMN/Non-DMN averages can be seen in Table 1.

	Low Egocentrism		High Egocentrism	
	Left hemisphere	Right Hemisphere	Left Hemisphere	Right Hemisphere
DMN1	2855.29(1331.22)	2931.51(1433.33)	3470.96(1152.31)	3534.89(1090.1)
DMN2	1553.68(881.91)	1589.43(895.52)	2570.51(1253.41)	2586.24(1234.3)
DMN3	2545.8(1694.76)	2535.92(1859.35)	4327.65(811.03)	4090.68(719.46)
DMN Mean	2318.26(1302.63)	2352.29(1396.07)	3456.37(1072.25)	3403.94(1014.62)
NON1	1761.38(1852.35)	1741.27(2144.15)	1762.66(765.31)	1864.32(908.93)
NON2	2089.88(1943.09)	2160.61(1951.95)	3450.54(3026.5)	3546.53(3130.62)
NON3	1602.73(2964.04)	1729.51(3185.28)	2308.63(1505.21)	2204.02(1970.13)
NON Mean	1817.99(2253.16)	1877.13(2427.13)	2507.28(1765.67)	2538.29(2003.23)

Table 1 - Mean(SD) values for sLORETA Activation Score for DMN and Non-DMN structures

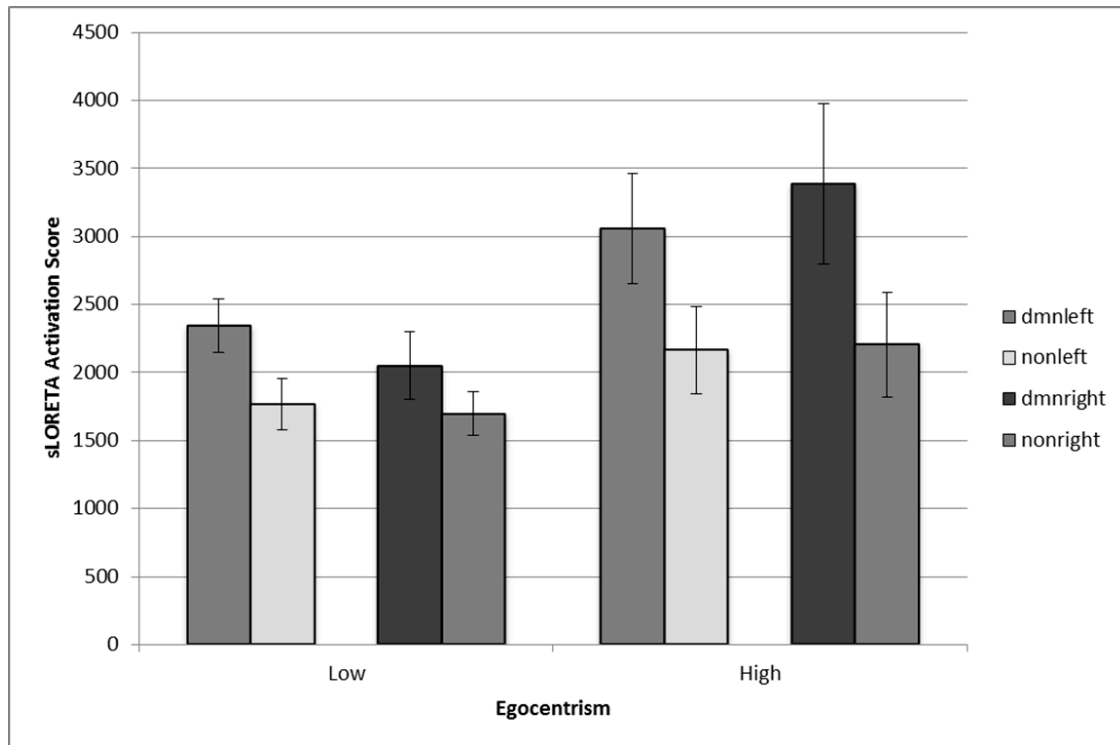


Figure 5 - sLORETA activation score within structures that were included as the Default Mode Network (dmn) and reference (non) structures in the left and right hemispheres for individuals who scored lowest (1/3) or highest (1/3) on the egocentric scale. Vertical bars indicated standard errors of the mean

As a control for endorsement of items, a reference 3-way ANOVA was employed for the two groups that formed the upper and lower third of the cluster scores for the six (6) other items in Table 2. Except for the expected differences in the activation score between the DMN and reference structures [(1,34)=19.00, $p < .001$; $\eta^2=36\%$] there were no significant main effects or interactions between the two groups with the upper and lower scores for the other items in Table 1 for activation scores.

Table 2 - Items contained with the primary cluster by which “egocentricity” is inferred (egomain) and the additional items included in the original PPI cluster. The (-) indicates a positive contribution required a no response

Egomain
Q37: Compared to other people, my memory is excellent.
Q48: I like to poke fun at people.
Q54: If there was a car accident, I believe I would have a better chance than most people to survive.
Q64: I am no different from anybody else. (-)
Q105: I like to spend time persuading people to do things.
Q135: I sincerely believe that I am very special.
Related Items
In addition to the six questions above:
Q51: There must be something more to life. (-)
Q57: My spouse or (girl or boy) friend should do what I want out of love for me.
Q74: When I have personal problems, talking to an older person is more helpful than talking to my friends.
Q77: Criticism and scolding hurt me terribly. (-)
Q95: Some people are so bossy that I feel like doing the opposite of what they request, even though I know they are right.
Q121: I lack self-confidence. (-)

One of the unexpected results was the large gender effect with respect to the hemisphericity of the power of DMN activity independent of egocentric scores. Three way analysis of variance as a function of gender, hemisphere, and DMN vs reference clusters demonstrated a statistically significant three way interaction [$F(1,52)=7.27$, $p < .01$; $\eta^2=12\%$]. Except for the main power differences between the DMN and reference clusters there were no other statistically significant effects. The *post hoc* analyses (Tukey's, $p < .05$) reiterated what is shown in Figure 7. For men the DMN cluster showed

higher activity in the right hemisphere compared to the left while for women the DMN cluster showed higher activity in the left hemisphere compared to the right.

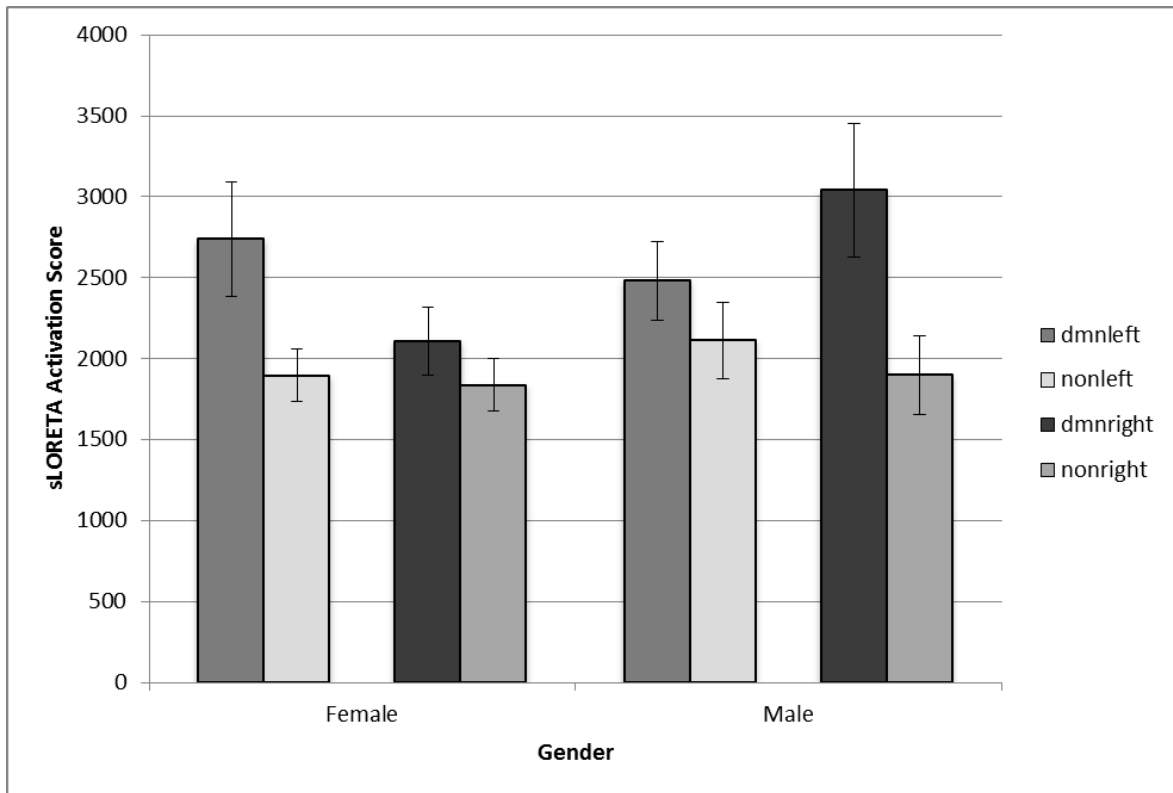


Figure 6 - sLORETA activation score within the structures included as the DMN or reference structures in the right or left hemispheres for men and women (n=54). Vertical bars indicate standard errors of the mean

3.4 Discussion

The results of this study support the hypothesis that individuals who display elevated power within cerebral structures associated with the classic components of the DMN are also more likely to score elevated scores on collections of items by which egocentrism is inferred. In this instance we are assuming the egocentrism reflects the propensity for the person to more confidently endorse his or her personal experiences as valid or “true” compared to people with lower scores. This pattern would also be congruent with our general model that self-appreciation or “self-bonding” to one’s own thoughts may be a consequence of the function of the structures involved with the DMN as well as its persistent occurrence when external stimuli are minimized or no act upon the environment is required.

The effect size in the increase in the power within the DMN structures was equivalent to a correlation of ~ 0.48 which is similar in magnitude to the magnitude of the correlation between Machiavellian egocentric scores and inferences of DMN activity reported by Sheng et al (2010). There are two major conclusions from this consistency of strength of association. First, psychometric tools of inferences for “common sense” and complex constructs such as “egocentrism” are replicable across experiments. Second, the often-maligned procedure of psychometric measurement for discerning magnitudes of a construct is reflected in quantitative alterations in brain function. Third, sLORETA reveals a powerful effect within the DMN that is more conspicuous than the psychometric means. We found the results to be revealing with respect to the potential convergence of traditional psychological constructs with the modern technologies, such as sLORETA.

Six items from the same inventory that were initiated included with the general “egocentric” scale but were found by factor analyses to be involved with a separate shared source of variance (Persinger & Makarec, 1983; 1992) were not significantly associated with differential activation of the DMN structures compared to reference structures. The absence of the effect suggests that specific types of affirmations concerning the self as indicated by endorsements of the PPI items are associated with quite different patterns of activation in the DMN as inferred by quantification of brain activity.

The second major result was the gender differences for the hemisphere in which the DMN power was most predominant. As noted in Figure 6, there was more activation of the left hemispheric DMN structures for females, while for the men there was more activation within the right hemispheric DMN structures compared to either hemisphere for the reference structures. Because structure dictates function, we would predict that the nature of egocentrism for men and women should differ. For women, the egocentrism would be more dominated by linguistic images and processes. In fact one would expect that awareness or exposure to syntax and semantics would contribute significantly to the strength of this egocentrism.

On the other hand for men, with a relative right hemispheric enhancement of the DMN, the egocentrism would be dominated by its properties. There would be less self-awareness of the etiologies for the egocentric references. They would be suffused with more affective (emotional) features and spatial relationships. Considering the theoretical and empirical studies that suggest the right hemisphere is the primary source of the “sensed presence” or “the other” which is often attributed with mystical or religious

significance (Persinger, 2003), one would expect that male egocentric themes would be more frequently dominated by convictions of “cosmic” consent or “selection”.

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Chapter 4

Elevated EEG spectral power following exposure to sequenced, physiologically patterned fields

Abstract

The effects of weak physiologically patterned magnetic fields upon human behaviour have been the subject of controversy, with implications that effects may be confined to specific pieces of hardware. In this study, field patterns employed in previous research were systematically applied through wave files in a variety of sequences through a different hardware configuration. Volunteers were exposed across their temporal lobes to a 20 minute primer field (40 Hz) followed by a 20 minute target field. It was composed of a burst-firing pattern known to elicit analgesia and one when applied as electrical current to hippocampal slices produces long-term potentiation. Participants exposed to either of the two target fields presented bilaterally only exhibited increased in power within the high beta range over the right frontal lobe. The same fields did not produce the effect when presented as the primer field, indicating that the sequence of field presentation was important. These effects were most robust for women relative to men. These results indicate that the sequence of field presentation may be crucial for producing discrete effects following the application of patterned magnetic fields.

4.1 INTRODUCTION

The effects of magnetic fields on behavior have been the subject of investigation for several decades. Transcranial Magnetic Stimulation (TMS) is now an accepted technique for altering behavior within the laboratory as well as within the clinical setting for the treatment of Depression and other mood disorders (Loo & Mitchell, 2005). While the biological effects of TMS are more readily accepted, effects of low-intensity extremely low frequency (ELF) fields on behavior have been viewed as more ambiguous. Whereas TMS operates within field intensities of 10^0 T range, low-intensity fields operate with an intensity of 10^{-6} T, several orders weaker than that of TMS (Persinger et al, 2010).

Reliable effects from these two ranges of magnitude may be neither contradictory nor incompatible. Persinger et al (2010) calculated that the magnetic energy within the cerebral volume during application of the microTesla fields would be sufficient to affect several hundreds of millions of action potentials each generating 10^{-20} J (Persinger, 2010). On the other hand the magnetic energy contained within this volume by the Tesla-range fields would be sufficient to compete with the approximately picoJoules per s of energy associated with glucose utilization. In other words the two technologies may be effective through different mechanisms: the electromagnetic fields associated with neurocognitive processes per se and the metabolic changes associated with glucose metabolism.

ELF exposure has produced a wide range of behavioural effects, such as magnetophosphenes perception, psychomotor effects, and changes in human electroencephalograph (EEG) recordings (Marino & Becker, 1977). A review by Cook et

al (2002) highlighted several studies describing changes in ERP characteristics due to ELF exposure. Sartucci et al (1997) found reduced N150 and P250 wave amplitude when participants were exposed to fields within the uT range. These two waves have been implicated in pain related somatosensory perception. Other fields (Martin *et al*, 2005) have been found to induce analgesic effects in rats equivalent to 4 mg/ kg of morphine. P300 ERP wave amplitude, involved in information processing, has also shown to be altered after exposure to ELF fields (Cook et al, 1992). Behaviourally, fields modelled after electrical current patterns sufficient to induce long term potentiation within the brain have been shown to enhance (Richards et al, 1996) scores for delayed memory of a complex narrative.

A variety of methodologies, measures, and characteristics have been studied in this general area. Much research has focused the effects of various frequencies from temporally symmetrical patterns such as sine or square waves. Applications of patterned fields may yield more information to the brain than just simple sine waves. Dynamic fields modelled after neuronal firing such as LTP (Richards et al, 1996) and firing of neurons within the amygdala (Martin et al, 2005) have been used by Persinger et al (2010) to produce a variety of quantitative changes within EEG activity and behavioural measures.

Although dynamic fields represent an improvement upon static field exposure, some research has shown that the presentation of several fields in a sequential order may produce a greater effect (Persinger et al, 1997). By applying fields first over the right hemisphere followed by bilateral exposure, St.-Pierre & Persinger reported greater success at eliciting EEG and subjective report changes (2006), demonstrating that it may

be important to use not only patterned fields, but using a specific sequence of patterned fields to elicit desired effects. The phenomena could be similar to those seen in neuropsychopharmacology. For example systemic injection of 3 mEq/kg of lithium chloride followed 4 hrs later by a subcutaneous injection of 30 mg/kg of pilocarpine produces reliable overt limbic epileptic seizures within 30 min. However the reversed temporal order of the injections does not elicit seizures or brain damage (Persinger et al, 1988).

The Shiva technology is a device developed by Todd Murphy was modeled to deliver magnetic fields through wave files rather than through a Digital-to-Analogue converter. However the shapes of the fields are modeled after those developed by Persinger & Koren. In both approaches the fields are applied through small solenoids (usually) over the temporal lobes. Weekly applications of fields generated by the Shakti technology, which produces fields in the same method as the Shiva technology but in a different configuration of solenoids, was found to produce elevations in alpha spectral power (Tsang et al, 2004). However the same Shakti technology was reported by Gendle & McGrath (2012) to produce no significant alterations in emotional responses to emotional images. However the latter study did not examine quantitative EEG changes.

In two separate examinations of the effects of the Shiva Helmet, which again utilized the same method of field induction but with 64-coils, the production of a counterclockwise, circumcerebral field elicited an out-of-body experience (Saroka et al, 2010) and both greater number of reported experiences and changes in participant EEG records (Collins & Persinger, 2013). The current study examines a different configuration of the Shiva Helmet. This configuration has 4 solenoids placed over each temporal lobe, similar to the

original Koren Helmet. Pairs of solenoids on opposite sides of the cerebrum are organized so that a field is generated between them. The purpose of this study is to systematically examine the different combinations of field conditions provided by the software to determine if this technology produces changes in reported experiences and in quantitative measures of EEG power. If the effects are as large as claimed or required for effective clinical application, the explained variance (η^2 estimates) should be above about 30%, that is enough to be clinically conspicuous, and hence should require relatively small sample sizes for statistical significance.

4.2 METHOD

4.21 Subjects

After approval by the university's Research Ethics Board, 24 (12 male, 12 female) university undergraduates volunteered to participate in the experiment. Their ages ranged from 19 to 27 years.

4.22 Procedure

Each subject was told he or she may or may not receive weak intensity magnetic fields. The subject sat in a comfortable chair in a quiet, dark room that was also a shielded acoustic chamber. An ELECTRO-Cap international electrode system with 19 AgCl electrodes was placed over the head and referenced to the ears for collecting monopolar EEG data. Impedance was maintained under 10 kOhms for each sensor. The EEG cap was connected to a portable laptop outside the chamber employing a Mitsar 201 amplifier

system. WinEEG version 2.84.44 working in Microsoft Windows XP was used to collect the EEG data.

While EEG equipment was being prepared for recording, participants were asked to complete the Personal Philosophy Inventory (PPI). It is a 140-item questionnaire designed to measure experiences associated with temporal lobe stimulation as well as belief systems (Makarec & Persinger, 1985). Factor analyses (Makarec & Persinger, 1990) have grouped the questions into a variety of relevant clusters that reflect classic experiences evoked by direct electrical stimulation or electrical lability within the temporal lobes. There are also scales that were designed to discern “yes” responding, misrepresentation, and exotic or traditional beliefs.

The Shiva helmet consists of 8 telephone jack solenoids obtained from Radio Shack. Four were placed over each side of the head (Figure 3). Solenoids were affixed to a square sheet of Velcro so they were separated 5 cm in the vertical plane and 8 cm in the horizontal plane. The Velcro squares were adhered on the sides of a baseball cap. As the Velcro squares were movable, the position of the square could be adjusted based upon size of participant head. Signals were rotated around the four solenoids on the right hemisphere in a counter-clockwise manner, while those on the left rotated in a clockwise manner. At any given time only one pair of solenoids (one on the left and one on the right side of the head) was activated. The magnitude of magnetic fields as measured by a power meter ranged from 1 μ T to 2 μ T in the center of the cap.

Signals were transmitted to the solenoids using *God Helmet Sessions for the Shiva Neural System Software* version 1H. This software was also designed by Professor

Murphy and employs 4 USB audio devices to send weak-intensity magnetic fields to the solenoids. The signals were derived from patterns described by Richards et al (1993). For this technology the digital-to-analogue signals had been transformed to audio-equivalents or wave files. Each USB audio device delivered the signal to two successive solenoids. The software generated ‘Amygdaloid’ and ‘Hippocampal’ patterns. The ‘Amygdaloid’ field was based upon the Burst-X field, which is modeled after the burst-firing pattern of neurons in the amygdala. This pattern has shown to be effective in producing an analgesic effect in rats (Martin *et al*, 2005), and modifying human affect (Freeman & Persinger, 1996). The ‘Hippocampal’ field was based on the pattern of electrical stimulation that produced LTP (Long-Term Potentiation) within the hippocampus (Rose et al, 1988).

These two target fields were preceded by “primer” fields, which were ‘40 Hz Modulated’ and ‘40 Hz Modulated Chirp’. They were variants of a 40 Hz wave frequency, which has been implicated as integral to the consciousness ‘binding’ factor (Llinas & Pare, 1991). Software settings allow for either 20- or 30-minute durations of both primer and target fields, for a total of 40 or 60 minutes respectively. These durations were selected because in many previous studies the strongest effects emerge after approximately 15 minutes of continuous field exposure (Persinger et al, 2010). A 40-minute duration was selected to minimize subject fatigue.

The software included eight primer-target combinations, summarized in Table 3. In six of these combinations, the primer field was presented over both hemispheres for 20 minutes, while the target field was presented unilaterally. In the case of the Amygdaloid field, the left hemisphere is exposed, while in the case of the Hippocampal field, it is the right

hemisphere exposed. In the remaining two combinations, the primer field is presented unilaterally while the target is presented bilaterally. Three participants were assigned to each of the eight field combinations. Although this sample size per group may be considered small, we reasoned that any effect that had potential clinical significance should be evident clearly with small samples and that similar effects in multiple smaller groups would be more indicative of both reliability and generalizability. We have also previously demonstrated differences between exposure to Shiva field and no field conditions (Collins & Persinger, 2013).

Table 3 - Sequences of Primer and Target fields

Condition	Primer Field	Target Field
1	40 Hz Chirp Bilaterally	Amygdaloid Left
2	40 Hz Modulated Bilaterally	Amygdaloid Left
3	Hippocampus Bilaterally	Amygdaloid Left
4	40 Hz Chirp Right	Amygdaloid Bilaterally
5	40 Hz Chirp Bilaterally	Hippocampus Right
6	40 Hz Modulated Bilaterally	Hippocampus Right
7	Amygdaloid Bilaterally	Hippocampus Right
8	40 Hz Chirp Left	Hippocampus Bilaterally

The subject was instructed to maintain closed eyes during the duration of the experiment. At the end of the experiment each subject completed an Exit Questionnaire listing 20 items (Persinger & Saroka, 2013; Persinger, 1999) of common experiences within the chamber. Each item was ranked according to the incidence of these experiences (0=no experience, 1=happened once, 2=occurred frequently). These experiences referred to

visual, auditory, tactile, vestibular and spatial anomalies as well as the sensed presence, out-of-body experiences, and a variety of emotions including fear and sadness.

4.23 Statistical Analysis

Raw spectral power was extracted from the EEG data within the WinEEG software. Thirty s samples were captured for each individual during baseline (before the fields were activated) and for every 5 minutes during field exposure (5, 10, 15, 20, 25, 30, 35, 40 min). The spectral analyses partitioned the EEG data into delta (0-3 Hz), theta (4-7 Hz), alpha (8 to 13 Hz), beta (14 to 20 Hz), high beta (20-30 Hz) and gamma (30+ Hz) bands. Channels were grouped by hemisphere and lobe (left and right: frontal, temporal, parietal, and occipital lobes). All statistical analyses involved SPSS 19.0 operating by Windows 7. Mean scores for subjective experiences were assessed by one-way ANOVAs. Analysis for EEG effects was completed using 2x2x3 mixed MANOVAs for primer field, target field, and time interval.

4.3 RESULTS

4.31 QEEG Profiles

The results of the analyses of variance as a function of the eight groups, and the pre- and post exposure measurements revealed a strong, three way interaction for EEG profiles over the frontal regions. Table 4 outlines the effect sizes for significant effects ($p < .05$). Although the majority of these effects were specific to the conditions and not to changes over time associated with exposure, there were several interactions between time and field. On the left hemisphere, there were significant differential changes in high beta and

gamma power. On the other hand, in the right hemisphere, the interactions between time and field condition occurred in the theta and high beta power bands.

Table 4 - Effect sizes for spectral power bands over frontal lobes by primer and target field conditions over time. All listed values significant at .05.

Hemisphere	Field	EEG Band	Pre	Post	Pre x Post	Time	Time x Pre	Time x Post	Time x Pre x Post
Left	Primer	Theta	0.4	0.26	0.44				
		Alpha	0.4	0.26					
		Beta	0.47	0.29					
		High Beta		0.31					
	Target	Theta	0.42	0.28				0.34	0.33
		Beta	0.47	0.36					
		High Beta		0.26					
		Gamma						0.27	
Right	Primer	Alpha	0.4	0.22					
		Beta	0.45	0.23					
		High Beta		0.29					
		Gamma		0.23					
	Target	Theta	0.4				0.3		
		Beta	0.44	0.25					
		High Beta							
							0.15	0.31	

Two conditions that were most similar were the ones that ended with a bilateral target field. They exhibited peaks at 35 minutes (e.g. Figure 8, right frontal high beta power). When participants were grouped according to those who had received unilateral stimulation of the target fields (conditions 1,2,3,5,6 & 7) and those who received bilateral stimulation (conditions 4 & 8), a statistically significant interaction between laterality and time interaction emerged. Post hoc analyses indicated the primary source of this interaction was the increase in power within the high beta range over the right frontal lobe ($F(4,168)=4.76$, $p<.001$, $\eta^2=.19$). At 35 minutes after the procedure began, or after 15 min of target field exposure, there was an increase in high beta power for individuals exposed to the bilateral target fields (Figure 9).

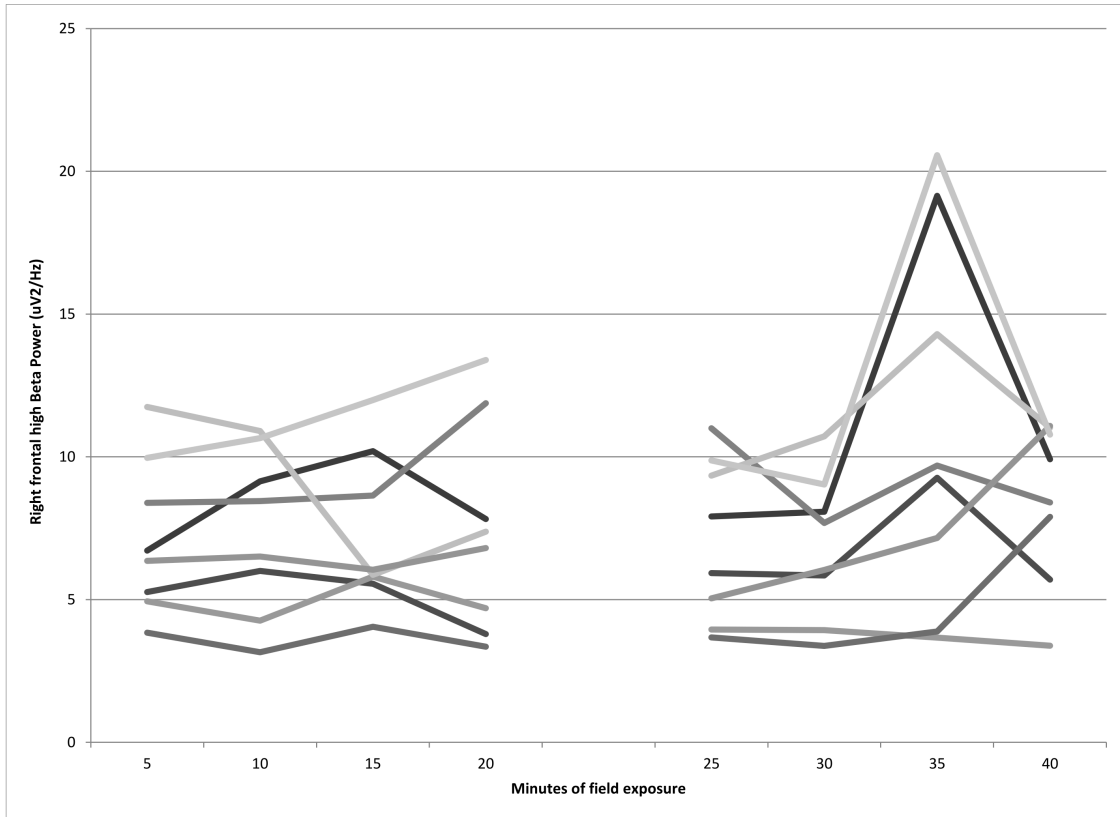


Figure 7 - Right frontal high beta power during field exposure for all eight field conditions across time

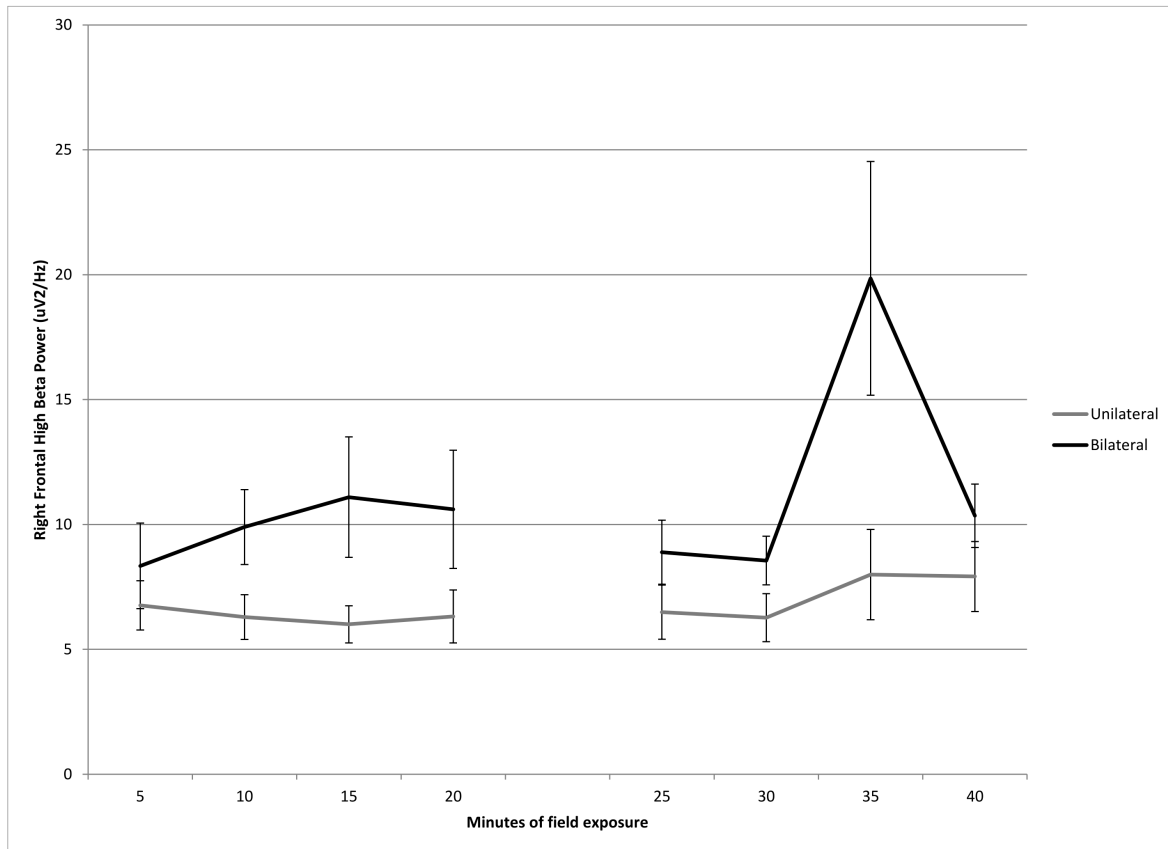


Figure 8 - Right frontal high beta power during field exposure by unilateral and bilateral target fields across time

Gender effects were examined to see if it could be a mediating role influencing the outcome. There was a significant interaction between gender and time within the high beta band over the right frontal lobe ($F(4,88)=2.79$, $p=.03$, $\eta^2=.12$). *Post hoc* analyses indicated that women displayed more power within this band than did the men (Figure 10). Similar to the unilateral/bilateral effect, this difference was most conspicuous at 35 minutes of field exposure. Bilateral exposure to fields for females was associated with more power within the high beta power in the right frontal lobe, particularly at 35 minutes ($F(4,40)=2.70$, $p=.03$, $\eta^2=.21$; Figure 11). There was no similar effect in male participants.

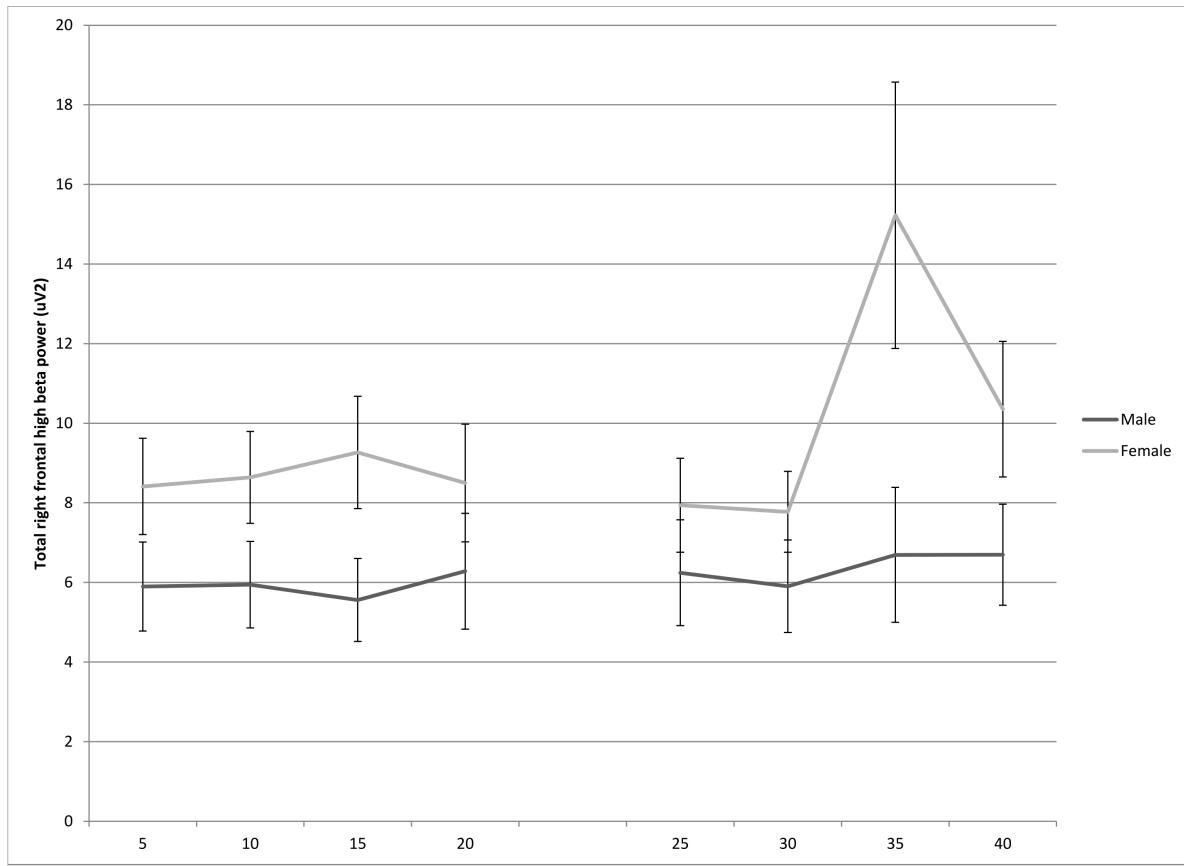


Figure 9 - Right frontal high beta power during field exposure by gender across time

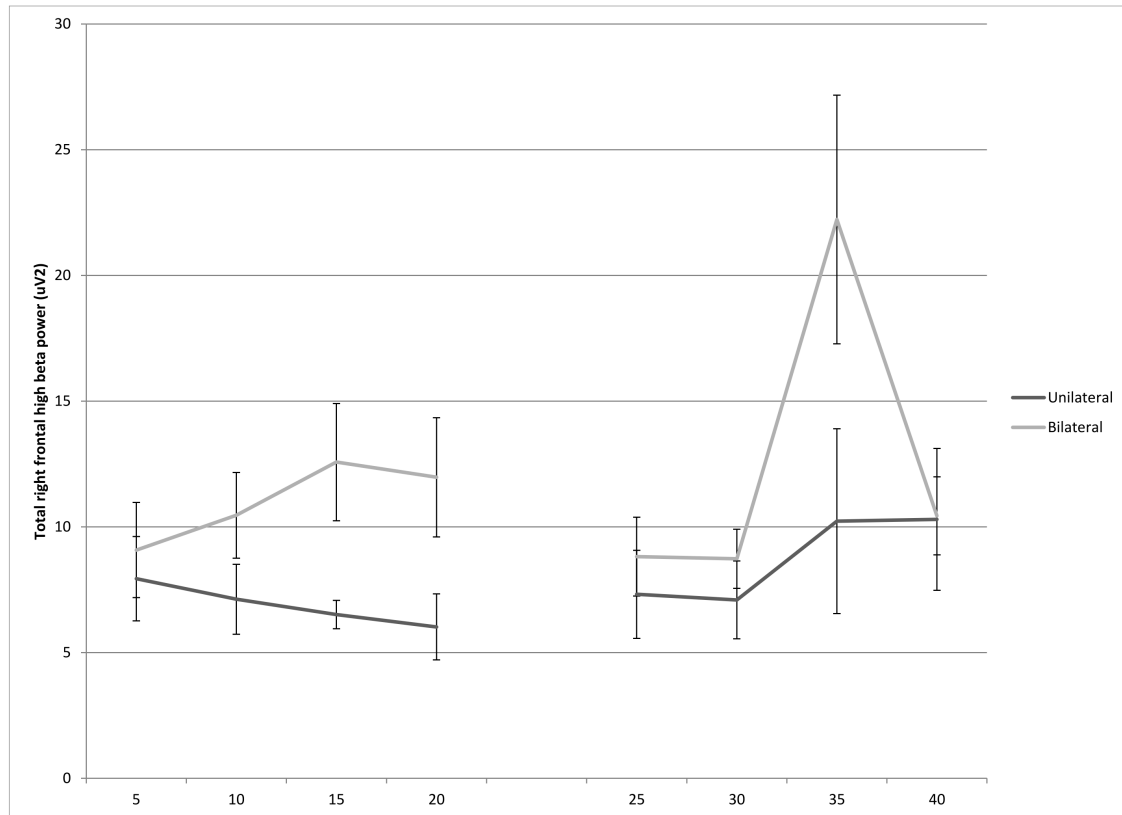


Figure 10 - Right frontal high beta power during field exposure for females by unilateral and bilateral field exposure across time

4.32 Subjective Experiences

Subjective experiences were examined using ANOVA analysis to compare all eight conditions. Only those items that refer to experiences like “fear or terror” and “memories” from the past showed differences in incidence for the different field sequences. When all eight conditions were compared, it was found that individuals exposed to bilateral Hippocampal fields followed by left hemisphere Amygdaloid fields reported significantly more frequent experiences of anger than most groups (Figure 12). When comparing groups only by primer (40 Hz) fields, there was a significant difference in reported cases of recalling instances from childhood (Figure 13). There were no significant group (field sequence) differences for the other types of experiences. Gender differences were also compared, with females reporting more cases of fear than males (Figure 14).

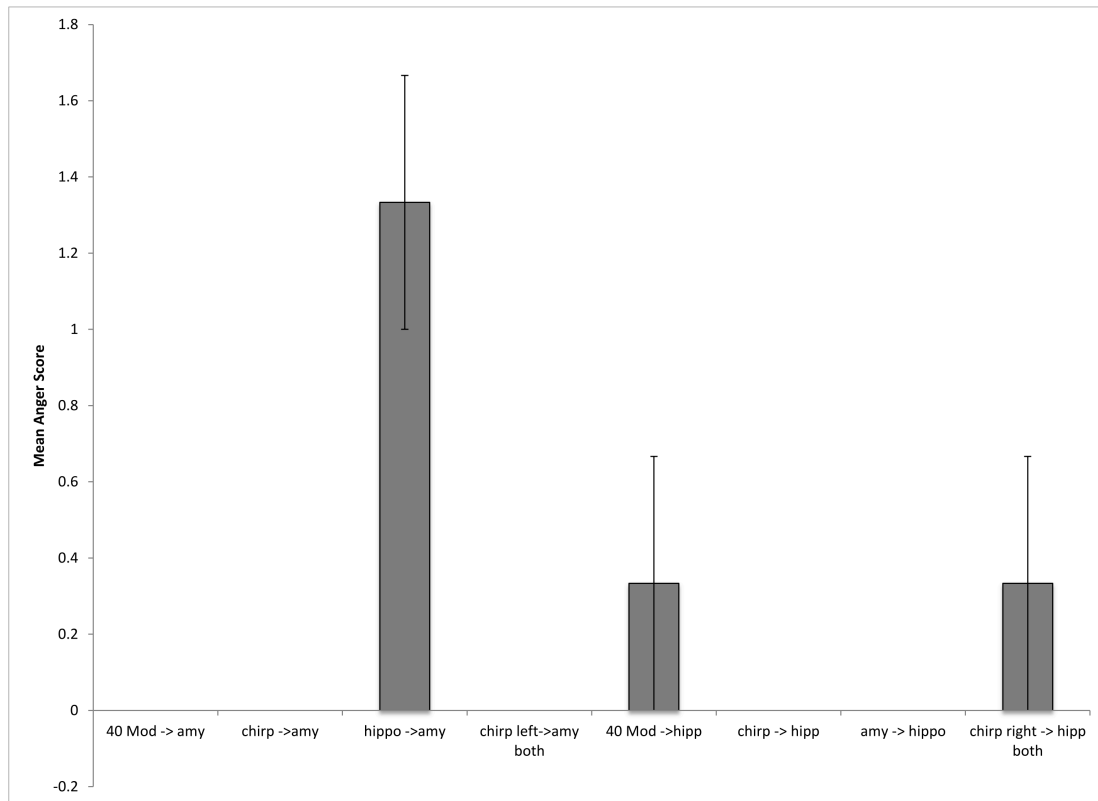


Figure 11 - Mean endorsement of ‘Anger’ experience questionnaire item during field exposure by field conditions

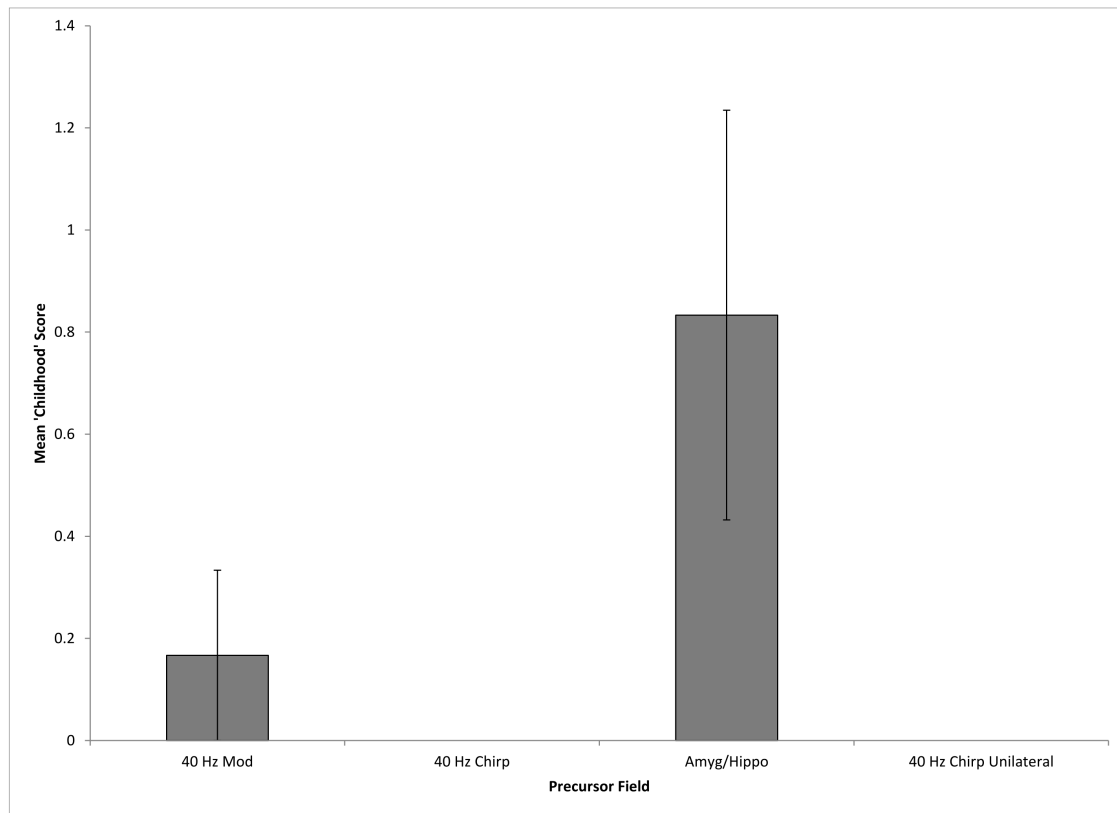


Figure 12 - Mean endorsement of 'Memories from childhood' experience questionnaire item during field exposure by Primer field

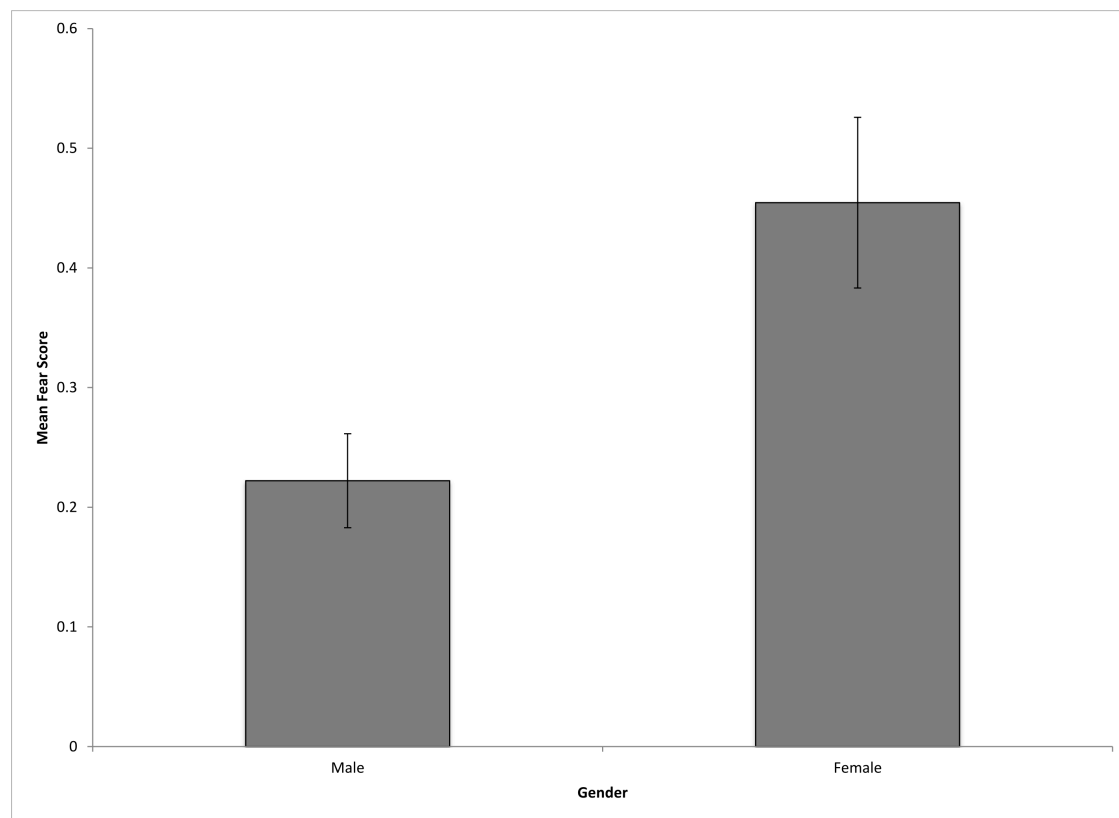


Figure 13 - Mean endorsement of 'Fear' experience questionnaire item during field exposure by gender

4.4 Discussion

This study is the first to examine in-depth the various fields included in the Shiva software, and although other studies have examined this method of administering fields in different hardware configurations (e.g. Tsang et al, 2004; Collins & Persinger, 2013), it is the first to examine this technique of producing fields in the Shiva God Helmet configuration.

This study was inconclusive at demonstrating a link between quantitative EEG changes and subjective experiences. Significant increases in high beta power activation over the right frontal lobe were not associated with reported subjective experiences during field exposure. However, subjective reports can be misleading, with momentary events being forgotten, or tendencies to portray oneself as normal or to appease the investigator. However, what is more significant is the fact that field exposure was related to quantitative EEG changes. Individuals exposed to bilateral fields modeled after neuronal processes had greater high beta activity in the right frontal lobe during exposure to the target field.

It is important to note the important role of the sequence of field presentation. In addition to the two groups who received bilateral target fields, two other groups also received the bilateral Hippocampal or Amygdaloid field, but as a primer field instead of a target field. The changes in power discussed above did not occur within these two groups, either during the bilateral primer exposure or during the unilateral target field. It is only when primed by a 20-minute primer field do these effects emerge.

This study also addresses some of the criticism leveled towards the validity of low-intensity physiologically patterned magnetic fields as an effective technique of producing changes in consciousness. Firstly, although there was no clear pattern of subjective experiences, there was a significant change in EEG activity as a result of specific field presentation. Many cortical processes that occur on an every day basis occur below the threshold of conscious perception (Lau & Passingham, 2007). That quantitative changes induced by a stimulus do not necessarily produce subjective experiences is not unusual, and even quite ordinary. Given the interaction between field effects and suggestibility described in the literature (Persinger et al, 2010), it may be possible that individual differences precluded the emergence of reported experience. Suggestibility itself as measured by the PPI was correlated only with experiences of a reoccurring idea, and not with number of reported experiences and ratings of overall experiences.

There still remain some unresolved questions. The link between EEG changes and subjective experiences is still unclear. Further research much be conducted with the Shiva helmet to assess if there is any link between the two. The Shiva helmet also includes 30-minute exposures of each field, for a total of 60-minutes, compared with the current study that used 40-minute trials. Although effects may be observed with longer application, results using the Koren helmet are generally observed within the first half an hour, and more specifically around the 15-minute point. It is significant that the effects observed during the bilateral target fields occurred at 15-minutes exposure.

4.5 References

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Chapter 5

Discussion

Experimental elicitation of mystical and altered states has repeatedly been produced within a controlled setting (Persinger, 2010). A variety of devices and methods have been devised to produce these experiences, with varying results. The current research adds to the literature both validation of certain field parameters and a relatively unexplored method of field delivery.

Chapter 2 of this thesis employed the Shiva technology in a 64-coil, circumcerebral configuration used in a previous case study (Saroka et al, 2010). Application of the Amygdaloid field produced stable power within the delta and theta bands over the temporal lobes; this is compared to the control condition, in which these bands were observed to increase over the course of the study. Because the experiment was conducted in a dark sound-proof chamber, this slow wave activity may be similar to that observed during drowsy states. The stability of low-frequency EEG bands for the field participants may indicate that this drowsiness was not increasing, either due to the effects of the fields to perhaps due to attending to the experiences reported by individuals exposed to the field.

Participants exposed to field conditions responded positively to several items on the exit questionnaire regarding out-of-body type experiences. These results are consistent with the observations from a previous study that involved this same hardware configuration, in which a spontaneous out-of-body experience was elicited. Although subjective reports

after the experience are useful, quantitative verification of EEG changes – in this case, lack of change – that accompanies the reports are useful in verifying that physiological differences are associated with the subjective experience. Although these specific effects may not necessarily be related to the recorded activity, this experiment replicated the effects observed in the case study of previous research.

Chapter 3 did not relate directly to the Shiva effects. However considering the role of the “intrinsic states of consciousness” or “the sense of self when all other stimuli are minimized”, the results were quite relevant and applicable. Measurements of underlying “personality constructs” and associated EEG baseline activity could be important for future attempts to control for potential confounding variables such as suggestibility. Elevated measures of self-reported egocentrism were associated with greater activity in structures related to the Default Mode when compare to areas not traditionally associated with this network. This compliments findings in other studies, which used a different questionnaire examining egocentrism resulted in similar findings (Sheng et al, 2010).

Comparisons between genders for the lateralization of Default Mode activation were conspicuous and congruent with the known general principles of sexual dimorphism of the human brain. Male participants had greater activation in Default Mode vs. non-Default Mode structures in the right hemisphere. Females exhibited an analogous activation in the left hemisphere. Although this must be investigated further, it could point to subtle differences in the construct of self that may result from hemispheric asymmetries.

The results of the study in Chapter 4 highlight the necessity of correct field specifications in producing measurable effects in brain activity. The study demonstrates that application of specific fields can produce quantitative changes in EEG activity. In this case, bilateral fields modeled after physiological activity within the amygdala and the hippocampus produced greater high beta over the right frontal lobe compared with only unilateral application. It is also important to note the sequence of field presentation. Bilateral, physiologically patterned fields produced greater high beta power in the right frontal lobe in participants who received these fields following a 20-minute precursor field. When participants were exposed to the same bilateral fields before receiving the precursor fields, this effect was not observed.

These studies addressed several criticisms that have been directed towards low-intensity, physiologically patterned ELF electromagnetic fields. Because previous studies using these particular fields have used hardware that was created in-house by the researchers themselves, there has been some concern that the effects may be specific to only this particular hardware. This would significantly limit the generalizability of the research to other contexts. By using a different method of applying the fields that also used hardware not constructed by the researchers, the effects observed in Chapters 2 and 4 contribute to the validity of the need to utilize specific field patterns. It does not matter which equipment is used or how the fields are produced; it is the specific pattern characteristics of the fields themselves, and the sequence in which they are applied that elicit quantitative changes in neural activity and reports of unusual experiences.

Several criticisms have been directed towards not only the types of magnetic fields studies in the current thesis but to the Shiva technology itself (Gendle and McGrath,

2012). The results of the current set of studies have shown that one version of the Shiva produced greater reports of out-of-body type experiences, corroborating previous findings using the same hardware configuration (Saroka et al, 2010). An alternate hardware configuration produced quantitative changes in EEG activity when using specific patterns of fields. That these individuals did not experience significantly more unusual events while exposed to the fields may not be surprising. A range of stimuli is able to evoke neuronal stimulation while remaining below the threshold of consciousness (Lau & Passingham, 2007). Further research must further determine how these field effects can interact with a variety of individual and personality characteristics that allow some individuals to be susceptible to field effects.

The Shiva technology is a commercially available product. Despite numerous anecdotal claims, there has been little research as to its validity in a controlled setting. These studies have shown that some of the provided fields may be more reliable than others in producing unusual experiences. Further research is needed to determine if the remaining fields are actually effective, or if they require an interaction with characteristics of the individuals in order to exert their effects. This study also cannot answer whether similar effects can be produced in a non-controlled setting. The studies were conducted in a sound-proof, dark, electromagnetically shielded chamber. Environmental distractions such as light and noise could potentially mask or even inhibit the often-subtle effects produced by this equipment. External electromagnetic fields from electronic equipment, 60 Hz fields from power lines, and the earth's geomagnetic fields may also interfere or mask the low-intensity fields used by the Shiva equipment, making it difficult to reliably produce a field that conforms to the specific patterns and intensities required. Future

research must compare exposure within a controlled setting to a variety of naturalistic settings in order to discern the ideal conditions in which consumers should be operating this equipment.

All conscious and unconscious phenomena have correlated physiological representations within the brain. This includes unusual experiences that historically have been ascribed to the religious or spiritual domains. Direct and inductive stimulation of the brain has a long history of evoking a range of perceptual, motor, and conscious phenomena. This has included a range of altered states, unusual perceptions, and mystical type experiences. The current studies contribute to the validity that low-intensity, ELF fields are able to create these experiences in a laboratory setting. The patterned fields developed by Persinger et al (2010) used in these studies are further validated. The effects observed in earlier studies were reproduced using alternate technology to deliver the same fields.

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